

X RAY PRECURSORS IN SGRs: PRECESSING γ JET TAILS

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ABSTRACT. Weak isolated X-ray precursor events before the main Gamma Ray Burst, GRB, and also rare Soft Gamma Repeaters, SGR, events are in complete disagreement with any Fireball, or Magnetar, one-shoot explosive scenarios. Fireball model in last two years has been deeply modified into a fountain beamed Jet exploding and interacting on external shells to explain GRB fine time structure. On the contrary earlier we proposed a unified scenario for both GRBs-SGRs where a precessing Gamma Jet (of different intensity) and its geometrical beaming is the source of both GRB and SGRs wide morphology. GRBs are peaked SNs Jet spinning and precessing observed along the thin Jet axis. Their mysterious weak X precursors bursts, corresponding to non-negligible energy powers, up to million Supernova ones for GRB, are γ Jet tails beamed off-axis, observed at X-Ray tails. They are rare, about (3 – 6)% of all GRBs, but not unique at all. Comparable brief X-ray precursor flashes occurred in rarest and most detailed SGRs events as the 27 and the 29 August 1998 event from SGR 1900+14. The same source has been in very power-full activity on recent 18 April 2001 once again preceded by X-Ray precursors. These events are inconsistent with any Fireball or Magnetar-Mini-Fireball models. We interpret them naturally as earlier marginal blazing of outlying X conical precessing Jet, an off-axis tails surrounding a narrower gamma precessing Jet. Only when the light-house Jet is in on-axis blazing mode toward the Earth we observe the harder power-full SGR event. We predict such a rich X-Ray precursor signals (more numerous than gamma ones) during Soft Gamma Repeater peak activities; they should be abundant and within detection threshold by a permanent monitoring SGRs by Beppo-Sax WFC or Chandra X ray satellites while at peak activity.

1. Introduction: GRBs and SGRs: Spinning, Precessing and Blazing γ Jet

Gamma Ray Burst and Soft Gamma Repeaters reached an apparent stage of maturity: tens of GRBs found, finally, an X, optical and (or) radio transient (the after-glow) identification as well as some associated host galaxies at cosmic red-shifts (Bloom et al 2000). New categories of GRBs and SGRs events have been labeled, but even within these wider updated data no conclusive theory or even partial understanding seem to solve the old-standing GRB/SGRs puzzle: the nature of The GRB-SGR signals. On the contrary the wider and wider collection of data are leading to a schizophrenic attitude in the most popular isotropic models, the Largest Cosmic Explosions (Fire-ball, Hypernova, Supra-Nova) with more and more phenomenological descriptions (power laws everywhere) and less and less unifying views. This "give up" attitude seem to reflect the surprising never ending morphologies of GRBs. We argued on the contrary since 1994 and in particular after 1998 that GRBs and SGRs find a comprehensive theory within a thin spinning and multi precessing γ Jet, sprayed by a Neutron Star, NS, or Black Hole, BH; the gamma jet is fed by electron pair GeV Jet in Inverse Compton Scattering. (Fargion 1994-1999, Fargion, Salis 1995-1998). Isotropic Fireball models, which enjoyed

a decade of total predominance, with the extreme GRB energy released ($\gg 10^{54} \text{ erg}$), comparable to few solar masses annihilation or more, lead to a deep conflict with any energy and masses. Indeed their corresponding Schwarzschild scale times are above milliseconds and disagree with the observed sharp GRBs fine time structures much below a fraction of millisecond. Fireball Isotropic models simply ignored the role of thermal neutrinos which imply at least twice the observed γ energy in GRBs. Fireball-Jet (a crazy acronym like the spherical-knife) mitigate the energy puzzle but cannot explain the huge wide energy range among known GRBs: indeed the energy power spread (from $10^{53} \text{ ergs}^{-1}$) for most far GRBs versus $10^{46} \text{ ergs}^{-1}$ for nearest GRB980425, led most Fireball defenders just to neglect, hide or even reject in a very arbitrary (and partisan) way the nearest and best identified GRB connection to a Supernova, SN, explosion as SN1998bw. We naturally interpreted this event as a slightly off-axis blazing Jet. We also understand the same rarity of GRB-SN detection and the established GRB980425-SN link as an additional evidence for the thin Jet nature of GRBs. Even originally (1970 – 80) unified GRB/SGR models since last fifteen years are commonly separated by their repeater and spectra differences; however very recently they openly shared the same spectra, time and flux structures (Fargion 1998-99, Woods et al 1999). This analogy suggest a common nature. Their different distances, cosmic versus galactic ones, imply different power source Jet. The γ Jet is born by high GeVs electron pairs Jet which are regenerating, via Inverse Compton Scattering, an inner collimated beamed γ (MeVs)-(tens KeVs) X precessing Jet. The thin jet (an opening angle inverse of the electron Lorentz factor, nearly milli-radiant), while spinning, is driven by a companion and/or an asymmetric accreting disk in a Quasi Periodic Oscillation (QPO) and in a Keplerian multi-precessing blazing mode: its $\gamma - X$ ray lighthouse trembling and flashing is the source of the complex and wide structure of observed Gamma Bursts. These γ Jets share a peak power of a Supernova ($10^{44} \text{ ergs}^{-1}$) at their birth (during SN and Neutron Star formations), decaying by power law $\sim t^{-1} - \sim t^{-(1.5)}$ to less power-full Jets that converge to present persistent SGRs stages. Indeed SGRs are blazing events from late relic X pulsar Jet with no associated explosion (or OT and afterglow) observable only at nearer distances in axis. The γ Jet responsible for SGR emit in general at $\sim 10^{35} \text{ ergs}^{-1}$ Jet powers comparable to the angular momentum losses; it is the thin angular collimation and not the Magnetar field budget, to lead to peak apparent SN powers $\sim (10^{44}) \text{ ergs}^{-1}$. In analogy GRB show an apparent luminosity of a SN $\sim (10^{44}) \text{ ergs}^{-1}$ amplified by the inverse square of the thin angle, from 10^{-3} to 10^{-4} radiant angle Jet beaming : the corresponding solid angle Ω spreads between 10^{-7} and 10^{-9} and the apparent amplification enjoy a huge factor: 10^7 up to 10^9 corresponding to GRBs . Optical-Radio After-Glows are not only the fading Supernovae explosion tails often observed in puzzling variable non monotonic decay, but they exhibit the averaged external Jet beamed tails moving and precessing while fading away. The rare optical re-brightening (the so called SN bump) observed in few afterglow might be erroneously associated to an underlying isotropic SN flash: it is probably the late re-crossing of the precessing Jet periphery toward the observer direction. The integral GRB-Jet activity may leave a trace triggering giant arc star formations.

A convincing evidence against any explosive GRB model, confirming present γ precessing Jet theory, is hidden in the in the recent GRB 000131 data which show an

un-explicable, for Fireball model, X precursor signal 7 sec long, just 62 seconds before to the huge main gamma trigger. No Fireball or Hypernova progenitor (binary NS or BH) could survive such a disruptive X ray precursor power $\gg 10^{48} \text{ erg sec}^{-1}$.

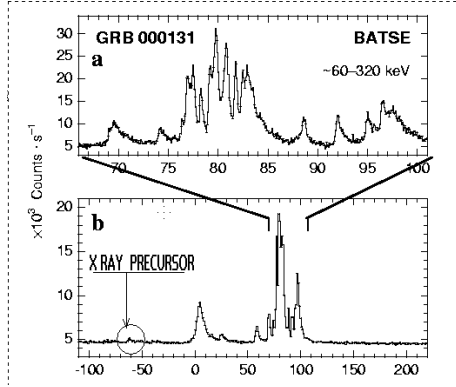


Fig. 1. Location and Intensity of early X Precursor in GRB000131

2. Are GRBs an Unique γ Jet Explosion?

As we noted above GRBs are not showing any standard candle behaviours within any Fireball isotropic model. Some moderate wide Fireball-Jet (a not conclusive compromise, like so called collapsar combining SN and open fountain-like Jet explosion) models with a large beaming (ten degree opening) can accommodate all cosmic GRBs excluding the "problematic" nearest *GRB980425* event keeping it out of the frame. Nevertheless SGRs, which share, some time, the same GRB signature, are themselves still within a popular isotropic mini-Fireball scenario powered by Magnetar explosive events. This model imply a magnetic energy in the neutron star at least 4 order of magnitude above the kinetic rotational energy, calling for an anomalous and unexplained energy equipartition bias. Beaming may solve the puzzle within a common X-ray Pulsar power.

Indeed the SGR1900+14 event BATSE trigger 7171 left an almost identical event comparable to a just following GRB (trigger 7172) on the same day, same detector, with same spectra and comparable flux. This Hard-Soft connection has been re-discovered and confirmed more recently by BATSE group: (Fargion 1998-1999; Woods et al 1999) with an additional hard event of SGR 1900+14 recorded in GRB990110 event. An additional GRB-SGR connection occur between GRB980706 event with an almost identical (in time, channel spectra, morphology and intensities) observed in GRB980618 originated by SGR 1627-41. Nature would be very perverse in mimic two signals, (even if at different distances and different powers), by two totally different source engines. The jet angle is related by a relativistic kinematics $\theta \sim \frac{1}{\gamma_e}$, where γ_e is found to reach $\gamma_e \simeq 10^3 \div 10^4$ (Fargion 1994, 1998). At first approximation the gamma constrains is given by Inverse Compton relation: $\langle \epsilon_\gamma \rangle \simeq \gamma_e^2 kT$ for $kT \simeq 10^{-3} - 10^{-1} \text{ eV}$ and $E_e \sim \text{GeV}$ leading to

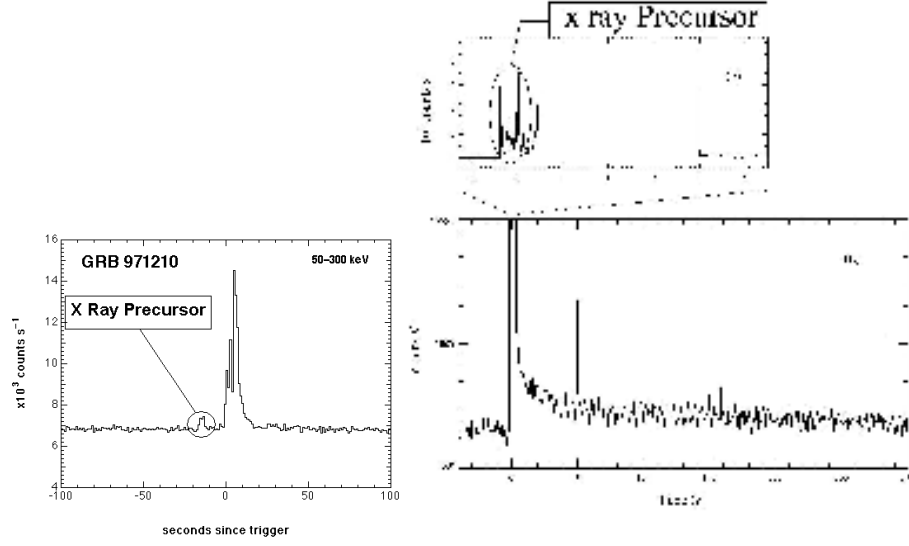


Fig. 2. Fig 2a and 2b: Time evolution and X precursors in GRB 971210 and SGR 1900 + 14 taking place on 27 August 1998

characteristic X- γ GRB spectra. The origin of GeV s electron pairs are very probably decayed secondary related to primary inner muon pairs jets, able to cross dense stellar target. The a-dimensional photon number rate (Fargion & Salis 1996) as a function of the observational angle θ_1 responsible for peak luminosity has been found:

$$\frac{\left(\frac{dN_1}{dt_1 d\theta_1}\right)_{\theta_1(t)}}{\left(\frac{dN_1}{dt_1 d\theta_1}\right)_{\theta_1=0}} \simeq \frac{1 + \gamma^4 \theta_1^4(t)}{[1 + \gamma^2 \theta_1^2(t)]^4} \theta_1 \approx \frac{1}{(\theta_1)^3} \quad . \quad (1)$$

The total fluence at minimal impact angle θ_{1m} responsible for the average luminosity is

$$\frac{dN_1}{dt_1}(\theta_{1m}) \simeq \int_{\theta_{1m}}^{\infty} \frac{1 + \gamma^4 \theta_1^4}{[1 + \gamma^2 \theta_1^2]^4} \theta_1 d\theta_1 \simeq \frac{1}{(\theta_{1m})^2} \quad . \quad (2)$$

These spectra fit GRBs observed ones (Fargion & Salis 1995). Assuming a beam jet intensity I_1 comparable with maximal SN luminosity, $I_1 \simeq 10^{45} \text{ erg s}^{-1}$, and replacing this value in adimensional expressions above we find a maximal apparent GRB power for beaming angles $10^{-3} \div 3 \times 10^{-5}$, $P \simeq 4\pi I_1 \theta^{-2} \simeq 10^{52} \div 10^{55} \text{ erg s}^{-1}$ within observed ones. We also assume a power law jet time decay as follows

$$I_{jet} = I_1 \left(\frac{t}{t_0}\right)^{-\alpha} \simeq 10^{45} \left(\frac{t}{3 \cdot 10^4 \text{ s}}\right)^{-1} \text{ erg s}^{-1} \quad (3)$$

where ($\alpha \simeq 1$ or $\alpha \simeq 1.5$) able to reach, at 1000 years time scales, the present known galactic microjet (as SS433) intensities powers: $I_{jet} \simeq 10^{39} - 10^{36} \text{ erg s}^{-1}$. We used the

model to evaluate if April 1998 precessing jet might hit us once again (as it possibly did on GRB980712). It should be noted that a steady angular velocity would imply (during the earliest few hours) an average intensity variability ($I \sim \theta^{-2} \sim t^{-2}$) corresponding to some of the earliest afterglow decay law. At later stages a rare re-beaming of the precessing Jet combined with a power Jet decay may alter the afterglow decay power law. Such a Jet blazing beaming and re-hitting may be the source of rarest re-brightening observed on GRB980508 and on GRB000301C after-glows.

3. X precursors in SGRs by Precessing Jet

We imagine the precessing Jet nature as the late stages of jets fueled by a disk or a companion (WD, NS) star. Their binary angular velocity ω_b reflects the beam evolution $\theta_1(t) = \sqrt{\theta_{1m}^2 + (\omega_b t)^2}$ or more generally a multi-precessing angle $\theta_1(t)$ (Fargion & Salis 1996):

$$\theta_1(t) = \sqrt{\theta_x^2 + \theta_y^2} \quad (4)$$

$$\theta_x(t) = \theta_b \sin(\omega_b t + \varphi_b) + \theta_{psr} \sin(\omega_{psr} t) + \theta_N \sin(\omega_N t + \varphi_N) \quad (5)$$

$$\theta_y(t) = \theta_{1m} + \theta_b \cos(\omega_b t + \varphi_b) + \theta_{psr} \cos(\omega_{psr} t) + \theta_N \cos(\omega_N t + \varphi_N) \quad (6)$$

where θ_{1m} is the minimal angle impact parameter of the jet toward the observer, θ_b , θ_{psr} , θ_N are, in the order, the maximal opening precessing angles due to the binary, spinning pulsar, nutation mode of the jet axis. Additional multi precessions are also possible leading to more complex and realistic γ burst evolution.

The angular velocities combined in the multi-precession keep memory of the pulsar jet spin (ω_{psr}), the precession by the binary ω_b and an additional nutation due to inertial momentum anisotropies or beam-accretion disk torques (ω_N).

The relativistic morphology of the Jet and its multi-precession is the source of the puzzling complex X - γ spectra signature of GRBs and SGRs. Its inner internal Jet contain, following the relativistic Inverse Compton Scattering, hardest and rarest beamed GeVs-MeVs photons (as the rarest EGRET GRB940217 one) but its external Jet cones are dressed by softer and softer photons. This onion like multi Jets is not totally axis symmetric: it doesn't appear on front as a concentric ring serial; while turning and spraying around it is deformed (often) into an elliptical off-axis concentric rings preceded by the internal Harder center leading to a common Hard to Soft GRBs (and SGRs) train signal. In our present model and simulation this internal effect has been here neglected without any major consequence. The complex variability of GRBs and SGRs are simulated successfully by the equations and the consequent geometrical beamed Jet blazing leading to the observed $X - \gamma$ signatures. As shown in Fig. 3 the slightly different precessing configurations could easily mimic the wide morphology of GRBs and SGRs as well as the surprising rare X-ray precursor observed in Fig.1.2 and simulated below for an event comparable to SGR1900+14 on August 1998. In conclusion the X-Ray precursor must occur often around main SGR γ event. We predict that such precessing Jet imprint must be soon found by continuous monitoring of active SGRs. The very recent

discover of such X-Ray precursors (Feroi M. et al, GCN 1060), at 2537, 755, and 444 s before the giant flare on 18 April with durations of 100, 125 and 55 ms, give additional support to our model predictions. The author thanks Pier Giorgio De Sanctis Lucentini and Andrea Aiello for kind support and numerical test.

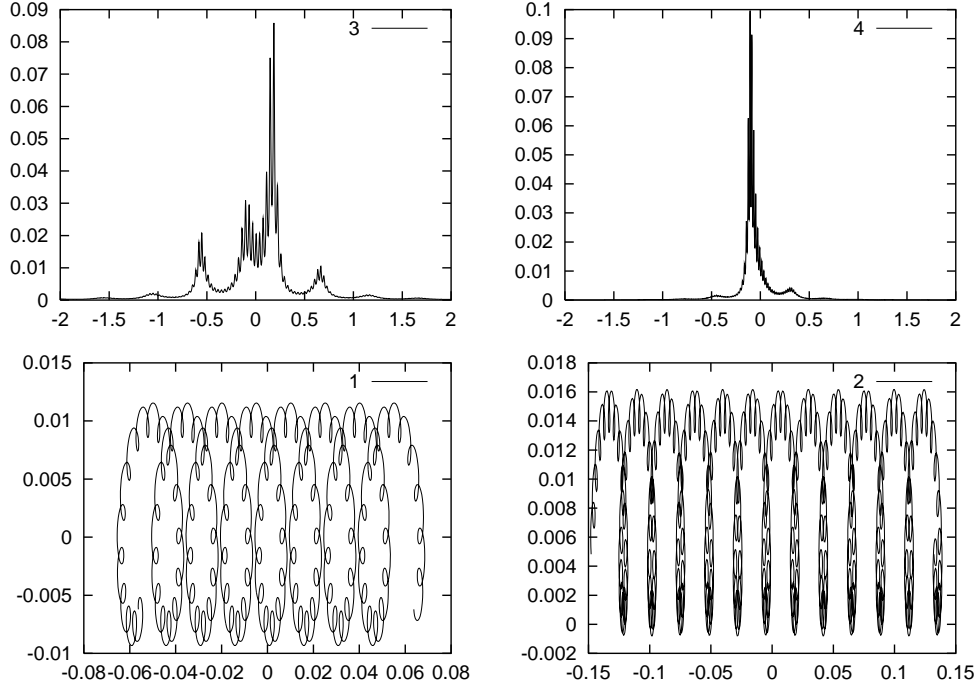


Fig. 3. Label 1 and 2 in Figure below show two different bi-dimensional angle Spinning, Precessing Gamma Jet ring patterns toward the detector at the origin (0,0). The corresponding Label 3-4 in Figure above show the consequent X, γ flux intensity time evolution derived by the ICS formula in the text. X ray precursors, as the events on August 1998 or on April 2001 from SGR1900+14 could be related to similar ideal or more complicated precessing beam Jet patterns.

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